JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1992, 57, 187-199 NUMBER 2 (MARCH)

FIXED-INTERVAL PERFORMANCE AND SELF-CONTROL IN CHILDREN

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Operant responses of 16 children (mean age 6 years and 1 month) were reinforced according to different fixed-interval schedules (with interreinforcer intervals of 20, 30, or 40 s) in which the reinforcers were either 20-s or 40-s presentations of a cartoon. In another procedure, they received training on a self-control paradigm in which both reinforcer delay (0.5 s or 40 s) and reinforcer duration (20 s or 40 s of cartoons) varied, and subjects were offered a choice between various combinations of delay and duration. Individual differences in behavior under the self-control procedure were precisely mirrored by individual differences under the fixed-interval schedule. Children who chose the smaller immediate reinforcer on the self-control procedure (impulsive) produced short postreinforcement pauses and high response rates in the fixed-interval conditions, and both measures changed little with changes in fixed-interval value. Conversely, children who chose the larger delayed reinforcer in the self-control condition (the self-controlled subjects) exhibited lower response rates and long postreinforcement pauses, which changed systematically with changes in the interval, in their fixed-interval performances.

Key words: fixed-interval schedules, concurrent schedules, impulsiveness, self-control, children

When operant responses emitted by normal adult humans are reinforced according to a fixed-interval (FI) schedule of reinforcement, two distinct patterns of responding are usually found. In the first of these (high rate), response rates are high and constant within the interval, with little or no postreinforcement pause being evident (Baron, Kaufman, & Stauber, 1969; Lippman & Meyer, 1967; Weiner, 1962, 1964, 1969, 1970). In the second response pattern (low rate), overall response rates in the interval are markedly lower, often with just a single response that is reinforced, or a group of responses starting just before the time at which the reinforcer becomes available (Buskist, Bennett, & Miller, 1981; Lippman & Meyer, 1967). It is clear, therefore, that the response patterns of normal humans under FI schedules are characterized by systematic interindividual differences.

These individual differences in reaction to the FI contingency may be related to other aspects of behavior on operant tasks. One of these is the "self-controlled" behavior exhibited on the self-control task. This procedure derives from studies with animals (e.g., Logue, 1988) in which subjects are offered a choice between a small reinforcer that is immediately available and a larger one that is available after a delay. By definition, choice of the smaller immediate reinforcer is called impulsive, and choice of the larger delayed one is called self-control. The technique has been extensively used in studies of different quantitative models linking response rate to reinforcer delay and magnitude (for a recent review, see Logue, 1988).

In the present context, the self-control procedure is of particular interest because of previous work on the developmental psychology of self-control in humans. For example, young children who have not yet mastered language have been reported always to choose the smaller, immediately available reinforcer (Miller, Weinstein, & Karniol, 1978). On the other hand, older children and adults usually choose the delayed reinforcer of greater magnitude (Miller et al., 1978; Mischel & Mischel, 1983; Sarafino, Russo, Barker, Constentino, & Titus, 1982). It has also been found that children who are classed as impulsive according to standard psychiatric classification methods (taken from the *Diagnostic and Statistical Manual of Mental Disorders,* 1980) are also impulsive in the operant self-control procedure, although the degree of impulsivity can

We are grateful to the teachers and pupils at the Ecole Albert Camus at Villeneuve D'Ascq for their welcome and help with the experiment. Reprints may be obtained from J. C. Darcheville, U.F.R. de Psychologie, Université Charles de Gaulle, Lille III, B.P. 149, 59653 Villeneuve d'Ascq CEDEX, France.

be reduced by repeated exposure to the self-control task (Schweitzer & Sulzer-Azaroff, 1988). The self-control procedure thus not only links factors that are important in behavior analysis, such as reinforcer rate, delay, and magnitude, but also provides an indication of impulsiveness or self-control in individual subjects that does not depend on subjective judgments or psychological tests.

A possible relation between self-controlled or impulsive behavior and low- or high-rate performance on FI schedules might be derived from suggestions raised by Sonuga-Barke, Lea, and Webley (1989a, 1989b) in their discussion of the development of self-control in children of different ages. They argued that mastery of self-control first involves learning to emit the reinforced operant response, then later learning when waiting is profitable in terms of outcome and when it is not. This idea is applicable to FI responding if we consider that subjects who wait before emitting the reinforced response (the low-rate responders who emit long postreinforcement pauses and few responses in the interval) benefit by not expending the effort of many unreinforced responses. Thus, subjects who can wait on the FI task (the low-rate responders) might be expected to be those who also exhibit self-control in the self-control procedure; conversely, impulsive behavior on the self-control task might be associated with high-rate responding on FI schedules.

The present experiment tested this conjecture by exposing 16 children to both FI and self-control contingencies. For all operant responses, access to either 20 s or 40 s of cartoons served as reinforcers. Eight subjects were initially exposed to various FI schedules, with the self-control training coming second. For another 8 subjects, the self-control training came first and the FI second.

METHOD

Subjects

The 8 children who received self-control training first (5 girls and 3 boys) were aged between 5 years 4 months and 6 years 9 months at the start of the experiment (mean age 6.0 years, standard deviation 0.46 years). The 4 girls and 4 boys who received FI training first were aged between 5 years 7 months and 7 years 1 month (mean age 6.2 years, standard deviation 0.50 years). Children were recruited from an elementary school close to Lille, and all were classmates.

Apparatus

For all subjects the experiment took place in a school, in a classroom isolated from external light and sounds. The experimental arrangement confronting the subject is shown in Figure 1. The child was seated at a table. In front of the child was a color monitor on which sequences of cartoons could be presented. Also on the table was a response box (25 cm wide, 25 cm high, and 9 cm deep) that consisted of three push-buttons and two translucent discs placed laterally, each of which could be illuminated either yellow, red, or green. A push-button was located just below each of the discs. These push-buttons (identified as "lateral buttons" in Figure 1) were not themselves illuminated, and served to register the choice responses of the subjects. A third push-button was situated in the center of the response apparatus, and there was also a fourth push-button (the independent button) that was not located on the apparatus. The experiment was controlled by an 80286 computer, located behind the monitor, which also recorded all the data.

We described the response apparatus to the children as a robot that could show them a cartoon (they had previously chosen one from a list of five offered) when they pressed on the different response buttons. The central button and the independent button were intended to be the equivalent of consummatory responses (see Logue, Peña-Correal, Rodriguez, & Kabela, 1986, for another example of an attempt to introduce consummatory-type responses in self-control tasks with human subjects); responses on the lateral buttons were those upon which reinforcers were contingent.

Subjects wore headphones that presented the cartoon sound track and also served to mask external noises. During periods when the reinforcer was not being presented, a continuous masking noise was present. Subjects were filmed throughout the sessions.

Procedure

Subjects 1 to 8 started their experimental conditions with the self-control procedure and finished with the FI, and Subjects 9 to 16

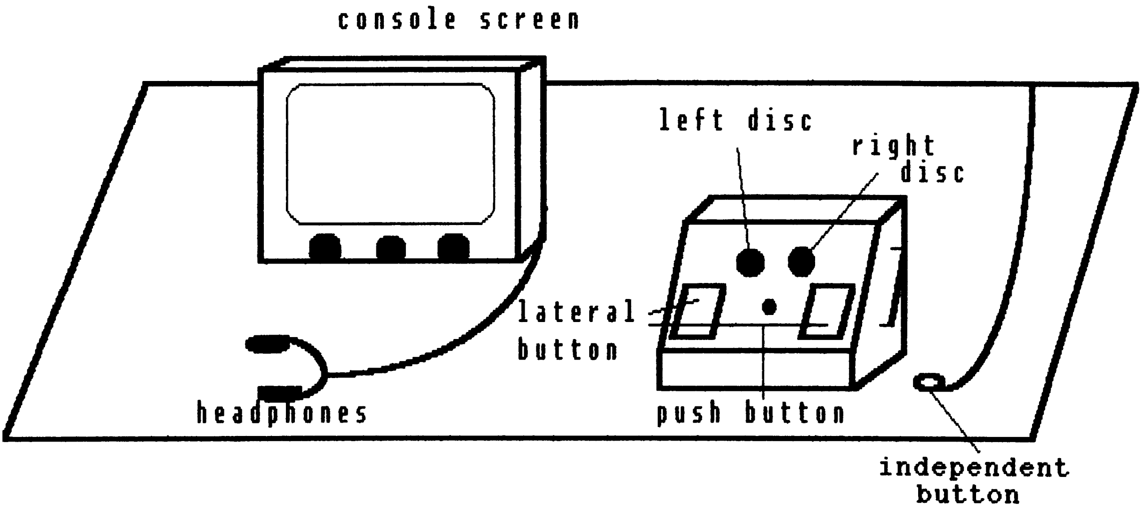

Fig. 1. Diagram of the response apparatus used in the experiment. The right and left discs could be illuminated either yellow, red, or green, and the different colors served as the discriminative stimuli during the self-control and FI phases (see Figure 2 for details of the self-control procedure). A response on the center push-button and then continuous pressure on the independent button were both needed to deliver and maintain the cartoon reinforcer. This was presented on the console screen, as shown, with the sound track delivered through the headphones.

received FI training first and the self-control procedure second.

Self-control procedure. In the first session the subject was seated in front of the apparatus and the monitor and was given the following instructions (translated literally from French), after which the experimenter left the room.

> You have in front of you a little robot which can give you the cartoon that you've chosen. You have to press the buttons to obtain it. Try the buttons until you succeed. Now, I'm going to put these headphones on you so that you can hear better and you'll be able to start. I'm going to put the light off so that you can see better.

Each subject received six conditions in the self-control phase. The number of sessions in each self-control condition except the first one was determined by a stability criterion that will be described below. Each session consisted of four forced-choice trials and 20 free-choice trials. The forced-choice trials were arranged by making only a single response alternative available; this ensured that responses on both alternatives were in the subject's repertoire. Figure 2 outlines the self-control procedure.

For the first free-choice trial, the two translucent discs were illuminated for 2 s with yellow, the stimulus present during the intertrial interval (ITI). Then, the discs changed color to green on the right and red on the left. When the child pressed the left choice button, the lights were extinguished during the prereinforcement delay period. When this delay ended, both discs were illuminated red. These red lights signaled that the reinforcer was available, and the child had to press the central button and the independent button to receive the reinforcer. The subject had to maintain continuous pressure on the independent button to receive the cartoon. If the child did not press or if the button was released the cartoon did not appear. Similarly, when the child pushed the right choice button, the lights were extinguished during the prereinforcement delay, and once the delay had passed both lit up green. The child then had to press the central button and the independent button, as described above. The duration of the reinforcer was measured from the start of the cartoon. After the reinforcer had been presented, the lights changed to yellow during the ITI, the duration of which was determined by the choice made.

During the forced-choice trials at the beginning of the session, the two discs were illuminated yellow for 2 s. Then either the left choice button (Trials 1 and 3) or the right one (Trials 2 and 4) was operative.

The total length of a trial, including presentation of stimuli, choice phases, reinforcer presentation and ITI, was 90 s. Postreinforcement times and ITIs thus varied as a function

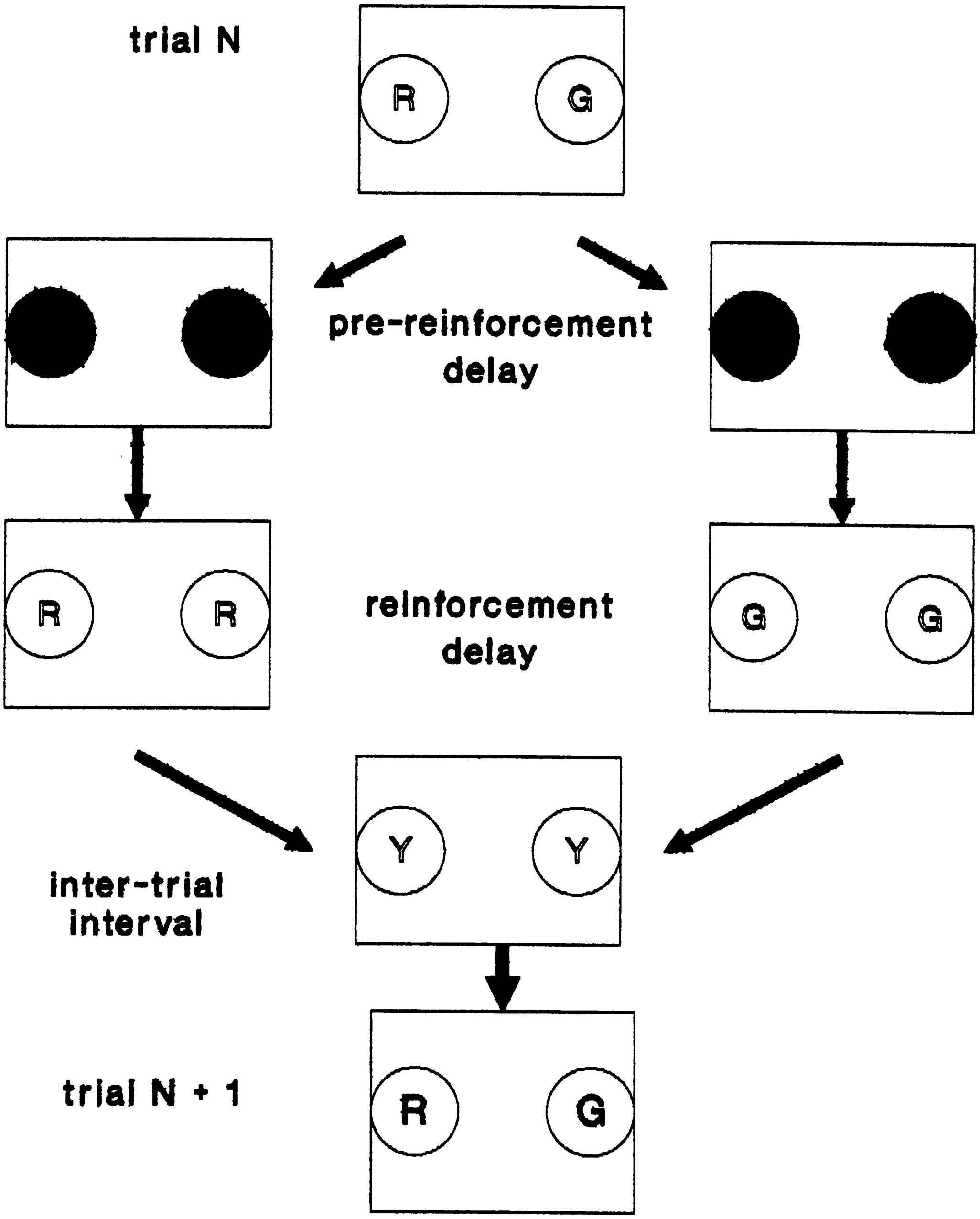

Fig. 2. Outline of the self-control procedure. R, G, and Y are red, green, and yellow, respectively.

of prereinforcement delay, assuming that subjects' reaction times made a negligible contribution to the total time. Stable performance was defined as two consecutive sessions in which the choice percentage for one or other of the reinforcer quantities did not vary or five consecutive sessions in which this measure did not vary by more than 10%.

The first session of the first condition served as training. Both prereinforcement delays were 0.5 s and reinforcer durations were 30 s. Table 1 shows the delay and reinforcer duration values for both choice buttons, left and right. Conditions 1 and 4 allowed measurement of left-right biases exhibited by subjects, if there were any such biases, because in these cases the delay of reinforcement was the same (0.5 s) for both alternatives and reinforcer duration was also the same (30 s). Conditions 2 and 5 counterbalanced left-right choices for the reinforcer delay and duration. In Condition 2 the 20-s reinforcer was available after a 0.5-s delay after responses on the left key, whereas the 40-s reinforcer was presented after a 20-s delay on the right key. Condition 5 reversed the assignment of these combinations of reinforcer delay and duration to the right and left keys. Conditions 3 and 6 investigated the effects of reinforcer duration per se, because in both conditions the delay of reinforcement for responses on both keys was 0.5 s, but in Condition 3 the 40-s reinforcer followed right-key responses and the 20-s reinforcer followed left-key responses. Condition 6 reversed the assignment of reinforcer durations to the right and left keys.

It should be noted that the reinforcement schedules arranging reinforcers for responses on the right and left keys were independent. Under another programming arrangement sometimes used in self-control studies (Logue, King, Chavarro, & Volpe, 1990), nonindependent schedules are employed in which each successive reinforcer is assigned randomly to one or the other key and must be obtained by responses on that key before further reinforcers are arranged. The nonindependent procedure has the advantage that the relative frequency of reinforcer delivery is not confounded with its duration and delay. With the independent procedure used here, for example, near-exclusive choice of one response alternative results in almost all reinforcers coming from that alternative, thus confounding duration and delay with rate. However, previous research has indicated that the use of nonindependent schedules with humans results in insensitivity to reinforcer delay and duration, to the extent that Logue et al. (1990, p. 363) strongly recommended against their use.

FI procedure. The apparatus and instructions were as for the self-control procedure, described above. Subjects who had previous self-control training were also told that the right choice button no longer functioned because there was no further choice of responses. The cartoon reinforcer was arranged solely for responses on the left choice button, followed by a response on the center button and one on the independent button.

The delivery of the reinforcer was programmed according to an FI schedule. The two green lights signaled that the response apparatus was functioning. When the child pressed the left button, the lights remained green until the interval elapsed. When the interval had elapsed, a response on the left button changed the color of the lights to red, and then a response on the center button followed by another on the independent button (held down continuously) delivered the cartoon sequence. Each subject received three FI schedules, FI 20, FI 30, and FI 40 s. Eight children (Subjects 1–4 and 9–12) received the schedules in the order FI 20, FI 30, FI 40 s; for the other 8 (Subjects 5–8 and 13–16), the order of presentation of the FI schedules was reversed. In addition, for each of these FI schedules, two reinforcer durations (20 s and 40 s) were arranged. Reinforcement periods were timed from the start of the cartoon. The different experimental conditions are described in Table 1, and the numbers of sessions of FI training for different subjects are shown in Table 2.

Table 1

Order of schedule presentation in the self-control and FI conditions. Al, Ar: reinforcer durations (in seconds) for left and right response alternatives. Dl, Dr: prereinforcement delays (in seconds) for left and right response alternatives. Order of presentation within each condition is shown by the number in the left column.

		Al	Ar	Dl	Dr
Self-control condition					
1		30	30	0.5	0.5
2		20	40	0.5	40
3		20	40	0.5	0.5
4		30	30	0.5	0.5
5		40	20	40	0.5
6		40	20	0.5	0.5
FI condition[a]					
1	6		FI 20	20-s reinforcer	
2	5		FI 20	40-s reinforcer	
3	4		FI 30	20-s reinforcer	
4	3		FI 30	40-s reinforcer	
5	2		FI 40	20-s reinforcer	
6	1		FI 40	20-s reinforcer	

[a] Left column for Subjects 1–4 and 9–12; right column for Subjects 5–8 and 13–16.

RESULTS

Self-Control Procedure

All the subjects learned to manipulate the buttons on the apparatus during the first session. The average session duration was 37.1 min, corresponding to 95 s per trial. Table 3 shows, for each subject in each condition, the

Table 2

Number of experimental sessions in the FI condition for each subject, shown for each FI value and reinforcer duration.

	FI 20		FI 30		FI 40	
Subject	20-s reinforcer	40-s reinforcer	20-s reinforcer	40-s reinforcer	20-s reinforcer	40-s reinforcer
1	11	9	13	7	15	6
2	8	6	11	8	10	5
3	15	10	8	6	11	6
4	10	8	10	5	8	8
5	7	6	11	6	7	6
6	12	8	15	10	13	9
7	14	11	12	9	12	5
8	11	8	8	7	10	6
9	16	12	10	8	15	7
10	8	6	7	6	7	5
11	9	8	12	8	11	9
12	13	8	17	11	15	8
13	16	10	14	9	18	10
14	10	9	10	7	10	8
15	11	8	18	9	13	7
16	9	7	12	8	9	6

average number of responses on each of the lateral buttons, during the free-choice period.

Conditions 1 and 4 allowed the assessment of any left-right bias, because in these conditions both the reinforcer magnitudes (30 s) and delays (0.5 s) were identical for responses on both keys. Overall, subjects tended to show a slight bias for responding on the left key in Condition 1 (10 of 16 subjects made more left-key responses than right-key ones, group mean percentage of left/total responses = 55%). Although the mean percentage of left/total responses increased to 60% in the other bias assessment condition (4), only 6 of 16 subjects showed a left-key bias in this condition. Between Conditions 1 and 4 some subjects drastically reversed preference, and changes in preference from left to right and vice versa were observable (e.g., S4 from 90% left responses in Condition 1 to 10% in Condition 4, S7 from 25% left responses in Condition 1 to 90% in Condition 4). Other subjects showed a virtual absence of bias in both conditions (e.g., S9, 55% left in Condition 1, 50% left in Condition 4), others showed small preference changes between Conditions 1 and 4, and 1 subject (S16) exhibited strong left-key bias in both Conditions 1 and 4. The reversals of bias shown by some subjects were difficult to interpret in terms of previous behavior. For example, the preference change shown by S4 might be attributed to carry-over from the preceding condition (Condition 3, in which the subject exhibited a 95% preference for the 40-s reinforcer available for right key), but S7 produced 100% right-key responses in Condition 3, then 90% left-key responses in Condition 4. Overall, the data did not exhibit any clear consistent left-right bias at the individual-subject level.

The results from Conditions 3 and 6 (see Table 3) showed that when both reinforcers were almost immediately accessible (with a 0.5-s delay), subjects almost always chose the larger. For example, in Condition 3, in which a 40-s reinforcer duration was available after a 0.5-s delay for right-key responses and the reinforcer duration was 20 s for left-key responses, S6 made 70% right-key responses, 8 subjects made 90% right-key responses, 4 produced 95% right-key responses, and 3 made 100% right-key responses. When the assignment of reinforcer durations was reversed (Condition 6), key preference was also reversed, with all subjects producing 80% or more responses on the key leading to the longer reinforcer duration.

Performance in Conditions 2 and 5 allowed behavior to be classified as either impulsive or self-controlled. Only Subjects 10, 11, 14, and 16 chose the larger delayed reinforcer more often in both Conditions 2 and 5. On the other hand, Subjects 4, 6, 7, 9, 12, 13, and 15 chose the immediate small reinforcer in both conditions. Finally, Subjects 1, 2, 3, 5, and 8 chose the smaller immediate reinforcer in Condition 2 but chose the larger delayed reinforcer in Condition 5. We can thus classify Subjects 10, 11, 14, and 16 as self-controlled and Subjects 4, 6, 7, 9, 12, 13, and 15 as impulsive. The fact that some subjects made self-controlled choices in Condition 5 (their second exposure to the self-control test) but not in Condition 2 (their first exposure) suggests that experience with the self-control task per se may influence performance. On the other hand, another procedural factor may distinguish subjects showing self-control in both tests from those showing it in the second one only, because all subjects of the first type received FI training as their first experimental exposure, whereas all subjects of the second type started with self-control. It is thus possible that experience with the FI schedule, or with the two different reinforcer durations experienced on the FI, played some role, although this is not conclusively proved by our data. Whatever the reasons for the fact that some subjects showed self-control in both Conditions 2 and 5 and others only in Condition 5, the total population of subjects showing self-control in one or both conditions included Subjects 1, 2, 3, 5, 8, 10, 11, 14, and 16.

FI Procedure

Figures 3 and 4 show postreinforcement pauses (upper panel) and running response rates (the response rate calculated during the period after the postreinforcement pause; lower panel) under the FI schedules as a function of the FI value and the duration of the reinforcer. Figure 3 shows data obtained when the reinforcer duration was 20 s, and Figure 4 shows data obtained when reinforcer duration was 40 s. Results are plotted separately for subjects who showed self-controlled behavior during at least one of the self-control conditions and those who were impulsive under the self-control procedure. The different groups of subjects behaved very differently under the FI, with self-controlled subjects exhibiting longer postreinforcement pauses and lower running rates than the impulsive subjects. Inspection of Figures 3 and 4 shows that there was no individual-subject overlap between the impulsive and self-controlled subjects on either postreinforcement pause measures or running rates.

For the self-controlled subjects, postreinforcement pauses (circles in the upper panels of Figures 3 and 4) often exceeded the FI value and generally increased systematically with increases in the FI. For example, when the reinforcer duration was 20 s, 8 of 9 self-controlled responders showed monotonic increases in postreinforcement pause value with increases in the FI; when the reinforcer duration was 40 s, 8 of 9 self-controlled subjects showed monotonic increases in postreinforcement pause with increases in the interval value. Response rates emitted by the self-controlled subjects (lower panels of Figures 3 and 4) were generally low (all group medians less than 11 responses per minute) and varied little as the FI value changed.

The FI performance of subjects who were defined as impulsive by the self-control procedure was very different, with short postreinforcement pauses (maximum group median 10 s), which changed little with changes in the FI value. When the reinforcer duration was 20 s, 3 of 7 impulsive subjects showed monotonic increases in pause with FI value; when the reinforcer duration was 40 s, none did. Response rates produced by impulsive subjects under FI were high (group medians ranged between 79 and 94 responses per minute) at both reinforcer durations and changed little with changes in the FI value.

As noted in the introduction, previous studies of FI performance in adult humans have found high-rate and low-rate behavior patterns. Although a precise numerical definition of high- and low-rate responding is lacking, our results tend to classify the self-controlled subjects as low-rate responders and the impulsive subjects as high-rate. For example, running rates produced by the impulsive subjects were about nine times higher than those produced by the self-controlled subjects, whereas postreinforcement pauses produced by the impulsive subjects were about one half to one quarter of the values produced by the self-controlled subjects, depending on condition.

Observation of the behavior of self-controlled subjects (i.e., those who exhibited low-rate response patterns) revealed responses relating to temporal control. For example, Subject 16 counted aloud during the interval, and Subject 10 always sang the same song while at the same time clapping his hands together. Another subject pressed the inoperative response button while counting, then shifted at the end of the interval to the operative button. All these sorts of behavior have been noted by other authors as occurring in subjects who are classified as low-rate responders on FI schedules (e.g., Bentall, Lowe, & Beasty, 1985; Lowe, Beasty, & Bentall, 1983; Lowe, Harzem, & Bagshaw, 1978).

DISCUSSION

The self-control procedure used in our experiment allowed subjects to be allocated to two groups, as those showing self-control or those who were impulsive. The impulsive subjects were, furthermore, apparently insensitive to the temporal regularity of the FI schedule, responding at a high steady rate in all FI conditions, whereas the self-controlled subjects behaved like low-rate responders showing a high

Table 3

Order of conditions, number of sessions, and mean number of responses on the left and right response alternatives for the self-control condition. Al, Ar: reinforcer durations (in seconds); Dl, Dr: prereinforcement delays (in seconds) for the left and right response alternatives.

Subject	Al	Ar	Dl	Dr	Number of sessions	Responses Left	Responses Right	Left/total responses
1	30	30	0.5	0.5	1	5	15	.25
	20	40	0.5	40	3	20	0	1.00
	20	40	0.5	0.5	2	2	18	.10
	30	30	0.5	0.5	2	10	10	.50
	40	20	40	0.5	3	17	3	.85
	40	20	0.5	0.5	2	18	2	.90
2	30	30	0.5	0.5	1	8	12	.40
	20	40	0.5	40	2	20	0	1.00
	20	40	0.5	0.5	2	2	18	.10
	30	30	0.5	0.5	2	9	11	.45
	40	20	40	0.5	2	20	0	1.00
	40	20	0.5	0.5	2	18	2	.90
3	30	30	0.5	0.5	1	13	7	.65
	20	40	0.5	40	4	19	1	.95
	20	40	0.5	0.5	3	0	20	0
	30	30	0.5	0.5	2	10	10	.50
	40	20	40	0.5	2	20	0	1.00
	40	20	0.5	0.5	2	20	0	1.00
4	30	30	0.5	0.5	1	18	2	.90
	20	40	0.5	40	6	18	2	.90
	20	40	0.5	0.5	4	1	19	.05
	30	30	0.5	0.5	5	2	18	.10
	40	20	40	0.5	5	0	20	0
	40	20	0.5	0.5	6	20	0	1.00
5	30	30	0.5	0.5	1	11	9	.55
	20	40	0.5	40	2	13	7	.65
	20	40	0.5	0.5	3	2	18	.10
	30	30	0.5	0.5	2	16	4	.80
	40	20	40	0.5	3	17	3	.85
	40	20	0.5	0.5	2	20	0	1.00
6	30	30	0.5	0.5	1	5	15	.25
	20	40	0.5	40	3	16	4	.80
	20	40	0.5	0.5	3	6	14	.30
	30	30	0.5	0.5	4	12	8	.60
	40	20	40	0.5	3	3	17	.15
	40	20	0.5	0.5	2	18	2	.90
7	30	30	0.5	0.5	1	5	15	.25
	20	40	0.5	40	4	20	0	1.00
	20	40	0.5	0.5	2	0	20	0
	30	30	0.5	0.5	2	18	2	.90
	40	20	40	0.5	2	4	16	.20
	40	20	0.5	0.5	2	17	3	.85
8	30	30	0.5	0.5	1	11	9	.55
	20	40	0.5	40	2	19	1	.95
	20	40	0.5	0.5	2	0	20	0
	30	30	0.5	0.5	3	11	9	.55
	40	20	40	0.5	3	16	4	.80
	40	20	0.5	0.5	2	18	2	.90
9	30	30	0.5	0.5	1	11	9	.55
	20	40	0.5	40	4	14	6	.70
	20	40	0.5	0.5	2	1	19	.05
	30	30	0.5	0.5	2	10	10	.50
	40	20	40	0.5	4	1	19	.05
	40	20	0.5	0.5	2	20	0	1.00

Table 3 (*Continued*)

Subject	Al	Ar	Dl	Dr	Number of sessions	Responses Left	Responses Right	Left/total responses
10	30	30	0.5	0.5	1	16	4	.80
	20	40	0.5	40	2	1	19	.05
	20	40	0.5	0.5	2	2	18	.10
	30	30	0.5	0.5	2	9	11	.45
	40	20	40	0.5	2	17	3	.85
	40	20	0.5	0.5	2	17	3	.85
11	30	30	0.5	0.5	1	12	8	.60
	20	40	0.5	40	3	3	17	.15
	20	40	0.5	0.5	2	1	19	.50
	30	30	0.5	0.5	2	10	10	.50
	40	20	40	0.5	2	20	0	1.00
	40	20	0.5	0.5	2	20	0	1.00
12	30	30	0.5	0.5	1	15	5	.75
	20	40	0.5	40	4	15	5	.75
	20	40	0.5	0.5	2	0	20	0
	30	30	0.5	0.5	2	13	7	.65
	40	20	40	0.5	5	4	16	.20
	40	20	0.5	0.5	2	19	1	.95
13	30	30	0.5	0.5	1	8	12	.40
	20	40	0.5	40	3	18	2	.90
	20	40	0.5	0.5	3	2	18	.10
	30	30	0.5	0.5	3	16	4	.80
	40	20	40	0.5	3	3	17	.15
	40	20	0.5	0.5	2	16	4	.80
14	30	30	0.5	0.5	1	12	8	.60
	20	40	0.5	40	2	2	18	.10
	20	40	0.5	0.5	2	2	18	.10
	30	30	0.5	0.5	2	11	9	.55
	40	20	40	0.5	2	20	0	1.00
	40	20	0.5	0.5	2	19	1	.95
15	30	30	0.5	0.5	1	10	10	.50
	20	40	0.5	40	4	17	3	.85
	20	40	0.5	0.5	3	2	18	.10
	30	30	0.5	0.5	4	8	12	.40
	40	20	40	0.5	3	3	17	.15
	40	20	0.5	0.5	3	19	1	.95
16	30	30	0.5	0.5	1	16	4	.80
	20	40	0.5	40	3	2	18	.10
	20	40	0.5	0.5	2	1	19	.05
	30	30	0.5	0.5	2	17	3	.85
	40	20	40	0.5	2	18	2	.90
	40	20	0.5	0.5	2	20	0	1.00

degree of sensitivity to the interreinforcer interval on the FI, often emitting only one or few responses close to the moment when reinforcer delivery was available.

There are similarities between these results and other work that has suggested relations between the impulsive/self-controlled behavior dimension and sensitivity to temporal variables on operant tasks. In particular, van den Broek, Bradshaw, and Szabadi (1987) studied the behavior of normal adults classified as impulsive or nonimpulsive according to three psychometric tests (Wechsler Adult Intelligence Scale, State-Trait Anxiety Scale, and Matching Familiar Figures Test) on differential-reinforcement-of-low-rate (DRL) schedules of reinforcement. They found that impulsive subjects responded at higher rates on DRL schedules, thus generally receiving a lower rate of reinforcement, than nonimpulsive subjects, and exhibited interresponse-time distributions that were much more poorly ad-

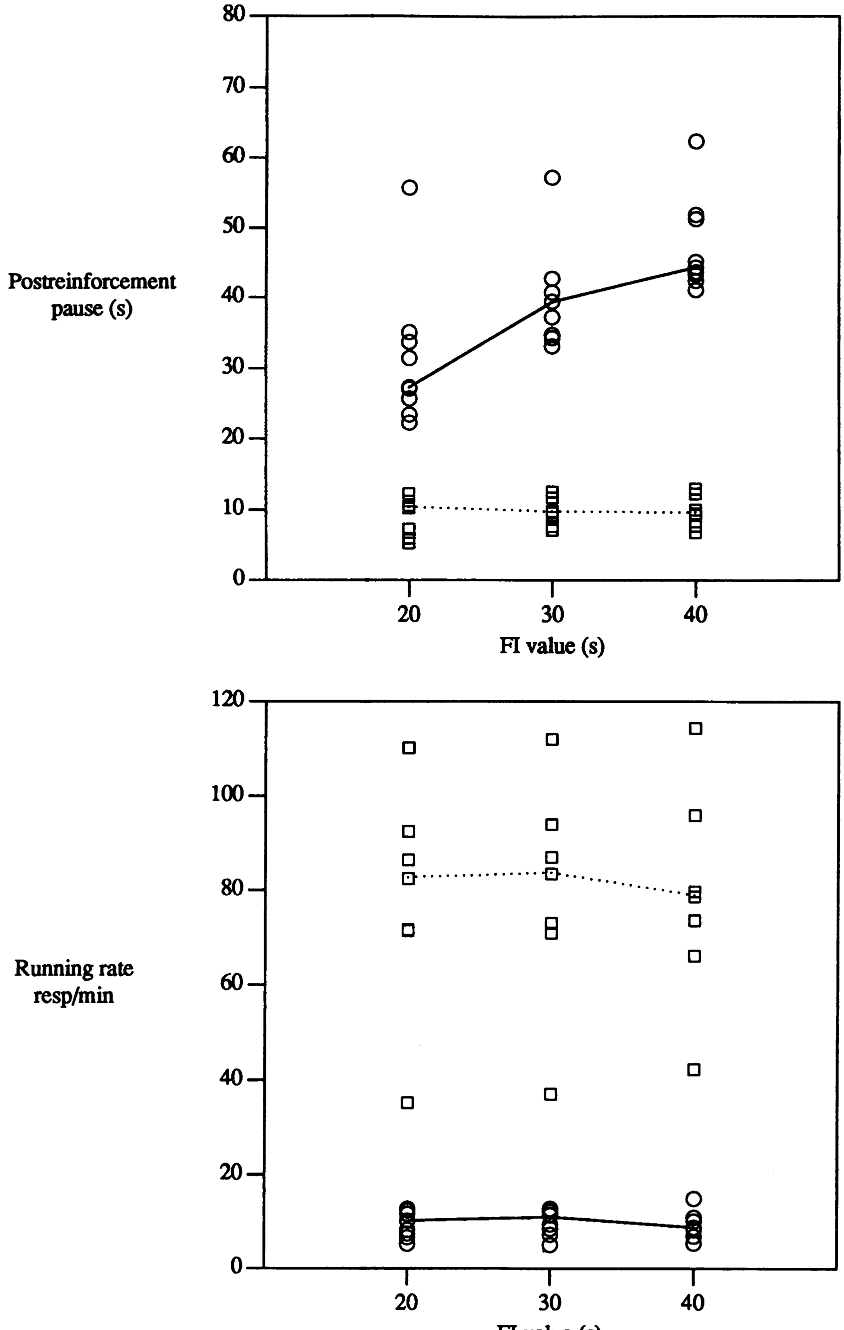

Fig. 3. Postreinforcement pauses (upper panel) and running rates (lower panel) from impulsive (squares) and self-controlled (circles) subjects in the FI conditions with a 20-s duration of access to the cartoon reinforcer. Data are plotted as a function of FI value. Solid lines connect the medians of the self-controlled group, dotted lines the medians of the impulsive group.

justed to the contingency requirements than those exhibited by the nonimpulsive subjects. One possibility suggested by van den Broek et al. (1987) was that the reinforcement contingencies, by themselves, exerted much poorer control over the behavior of impulsive than nonimpulsive subjects, but that in some cases the performance of impulsive subjects could be

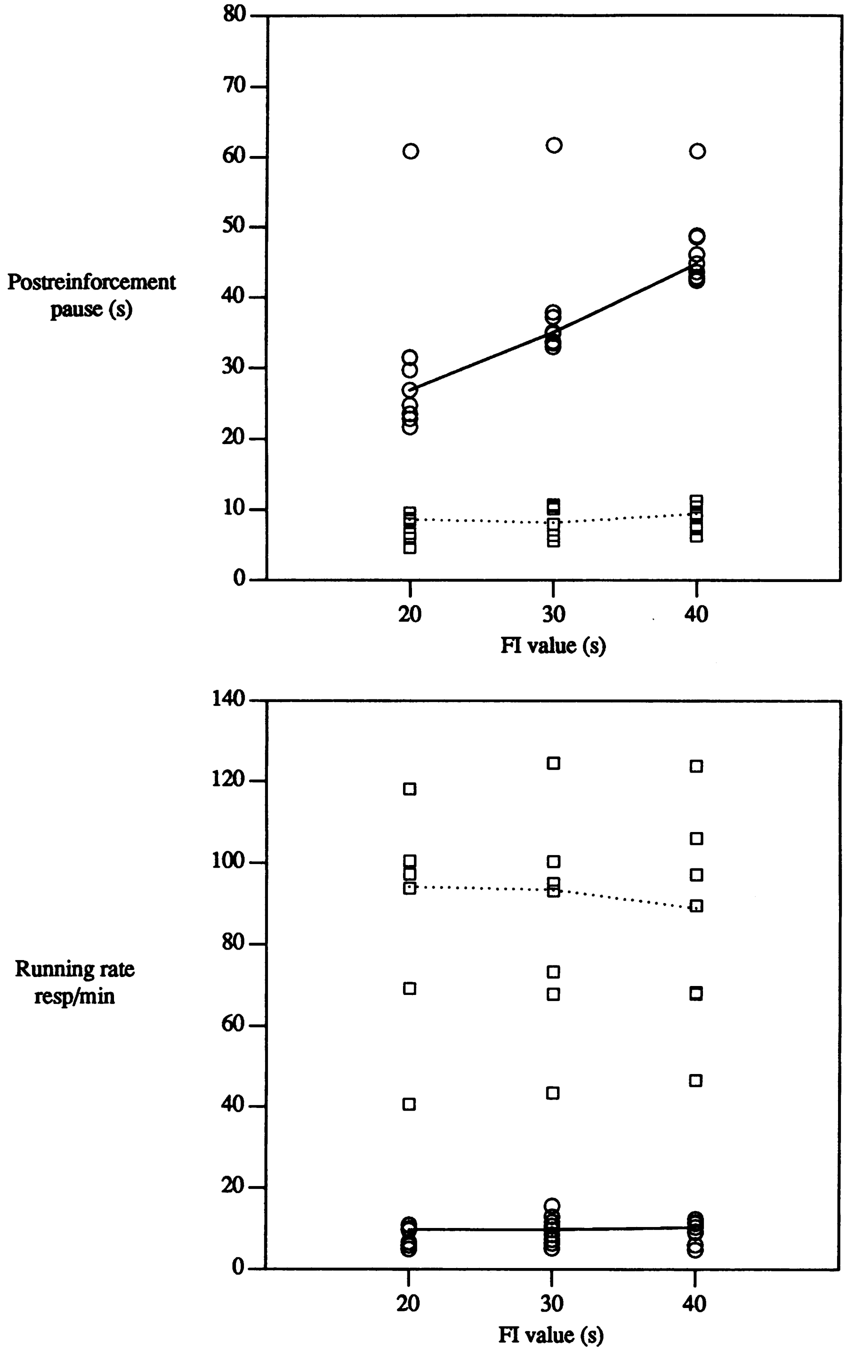

Fig. 4. Postreinforcement pauses (upper panel) and running rates (lower panel) from impulsive (squares) and self-controlled (circles) subjects in the FI conditions with a 40-s duration of access to the cartoon reinforcer. Data are plotted as a function of FI value. Solid lines connect the medians of the self-controlled group, dotted lines the medians of the impulsive group.

improved by external cuing that provided relevant information about the contingencies. In their Phase 2, van den Broek et al. signaled the availability of the reinforcer by means of illumination of a light. This stimulus initially controlled the behavior of the nonimpulsive subjects much more than that of the impulsive subjects, but eventually both groups showed some evidence of control. In a subsequent phase of the experiment, van den Broek et al. supplemented the light illumination by instructions, as follows: "The way to earn points is by delaying your button-press until the red light comes on. You should only press when the light is on" (p. 235). This instruction improved the performance of both impulsive and nonimpulsive subjects. Finally, the signal light was suppressed and performance declined somewhat in both groups, although much more markedly in the impulsive subjects (who made more than 50% of responses with nonreinforced interresponse times).

The results of van den Broek et al. (1987) suggest that the behavior of impulsive subjects might be insensitive to internal cues, such as those arising from temporal regularities in reinforcement schedules or relations between behavior and reinforcement, but their performance might be more readily controlled by external signals correlated with contingencies, particularly when instructions make clear in what way the stimuli and contingencies are correlated. On an FI schedule, as in the present experiment, no external cue signals reinforcer availability; thus, subjects must rely on internal cues arising from, for example, postreinforcement time. Consistent with van den Broek et al.'s results, we found in the present study that the temporal regularities of the FI schedule exerted poor control over the behavior of impulsive subjects, whereas the behavior of the subjects exhibiting self-control in the self-control test was well-adjusted and sensitive to the temporal features of the FI schedule.

Our results suggest that high-rate responding on FI schedules and impulsive behavior are linked, so that one might be used to predict the other. It is also possible that impulsive subjects may behave differently from nonimpulsive ones on other temporally defined schedules (see Pouthas, Macar, Lejeune, Richelle, & Jacquet, 1986, for discussion). With information about performance on a wider range of reinforcement schedules, one might thus be able to define a constellation of related types of operant behavior, such that the existence of one sort of behavior gives an above-chance prediction of performance in other sorts of situations. Such a development would certainly permit a more precise treatment of individual differences in operant responding than has been so far possible (e.g., for a discussion of individual differences in operant behavior see Harzem, 1984).

Both biological factors predisposing subjects to display certain types of behavior and different organismic histories have been proposed as causes of individual differences in operant responding (Harzem, 1984). The possible involvement of some sort of impulsivity/self-control dimension in the control of behavior under FI schedules is particularly interesting, given that the possible causes of individual differences in impulsivity have been the subject of previous research. One suggested variable has been the socio-economic level of the subjects used. For example, Bresenham and Shapiro (1972) proposed that the behavior of subjects from lower socio-economic groups was affected more by probability of reinforcement than by magnitude, whereas the reverse was true for subjects from more favored backgrounds. Several studies have also discussed the relation between reinforcement probability, reinforcement delay, and reinforcement magnitude (e.g., Rachlin, Castrogiovanni, & Cross, 1987). Obviously, individual differences in sensitivity to any of these factors are likely to produce marked individual differences in operant responding on a variety of tasks.

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Received March 27, 1991
Final acceptance October 29, 1991